

AS 7637:2014



Hydrology and Hydraulics



Infrastructure Standard



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Preface

The aim of this Standard is to describe the hydrological and hydraulic requirements (functions, performance, design constraints and risk attributes) for the design and assessment of railway infrastructure in relation to whole-of-life approach to the management of hydrological and hydraulic design. This approach includes the requirements in relation to hydrological and hydraulic requirements in terms of design, supply, construction and maintenance of track in relation to drainage and flood-prone areas for a range of operational track gauges used in Australia.

For the purposes of this Standard, all clauses containing the term 'shall' are considered mandatory requirements; all clauses containing the term 'should' are considered recommendations, and all other clauses are explanatory statements.

All RISSB standards provide controls for hazards contained in RISSB's hazard guideline. In this particular standard, the reference number of the hazard being addressed is identified in an attached appendix. RISSB's hazard guideline can be found on the RISSB website at www.rissb.com.au.

1 Introduction

1.1 Purpose

This Standard describes the hydrological and hydraulic requirements (functions, performance, design constraints and risk attributes) for the design and assessment of railway infrastructure in relation to all forms of drainage and flood-prone areas.

This Standard is intended to govern public and private railways and railway drainage systems on a whole of life basis, and any other drainage related work affecting the rail corridor.

The subgrade is considered to be equally important for track performance as rail and ballast, and the main purpose of this Standard is to provide a framework that promotes consistency and efficiency in design, construction, commissioning, maintenance, monitoring and decommissioning of track drainage and waterway crossings.

This Standard is concerned primarily with the hydraulic design of surface and sub-surface drainage systems including river and floodway crossings, culverts, pipes, channels, pits and grates.

1.2 Scope

The scope of this Standard covers hydrological and hydraulic requirements for construction of new railways and maintenance of existing lines. Requirements to be considered include:

- (a) drainage and stability of the track formation, supporting embankments, associated cuttings (including rock faces) and access roads adjacent to the track
- (b) all track, whether placed on natural surface or constructed on formation or structures such as bridges and concrete supports
- (c) levees, basins, diversion drains, stream training and interconnecting catchments.

This Standard covers the management of surface run off only, through either above or below ground (underground) drainage systems, but is not intended to cover the management of ground water flows (i.e. hydrogeology).

While this Standard will not exhaustively cover all possible hydrological or hydraulic circumstances, or address the impacts of hail and snow, its scope does include both surface and underground drainage requirements arising from within the railway corridor as well as similar needs arising from the interface with natural waterways along the corridor.

- (a) All drainage (inclusive of surface and underground drainage) should be considered in all stages of the track lifecycle.
- (b) Surface and underground drainage systems serve to intercept and direct surface water, keeping it flowing so that it runs off and is controlled and redirected away from the track structure
 - i. Commonly used surface drainage systems include cut-off drains (along top of cuttings), bench drains, cess drains, mitre drains, culverts, diversion drains.
 - ii. Underground stormwater drainage systems collect and transfer stormwater below ground level to a suitable discharge point. Commonly used underground drainage systems include cross-drains with grates and pits (for yards and stations) and French drains (shallow drains for confined yards)
 - iii. Underground stormwater drains are often used where adequate surface drainage cannot be provided due to some restriction or lack of available fall due to outlet restrictions. Example locations include station car parks, platforms, cuttings, junctions, bridges, access roads, stabling yards and intermodal terminals.

Since water is the principal influence on stability of the track, formation, cuttings and embankments control of surface and sub-surface water is the most important factor in corridor design and maintenance.

A balanced system is made up of a drainage system appropriately sized to handle the expected flows and dispose of the water without accumulation or excessive saturation

Limiting flow velocities are to be appropriate for the avoidance or prevention of erosion of the soil type or types through which the system passes.

This Standard covers rail networks classified in AS 7630.

This Standard is not specifically intended to cover urban on-street tramway or light rail networks, cane railways, or heritage railways operating on private reservation, but items from this Standard may be applied to such systems as deemed appropriate by the relevant Railway Infrastructure Manager.

- (a) This Standard is not intended for use in the design and operation of monorail networks, or miniature or amusement park railways.

1.3 Compliance

There are two types of controls contained within the RISSB Australian Infrastructure Standards: 1. mandatory requirements; and 2. Recommended requirements.

Both of these types of control address hazards that are deemed to require control on the basis of existing Australian and international infrastructure practices and standards.

A mandatory requirement is a requirement that the Standard sees as the only way of treating the hazard.

A recommended requirement is one where the Standard recognises that there are limitations to the universal application of the requirement and that there may be circumstances where the control cannot be applied or that other controls may be appropriate or satisfactory, subject to agreement with the Railway Infrastructure Manager.

Recommended requirements in the RISSB Australian standards are considered when compliance with this Standard is being assessed.

Where conflict arises between a referenced standard and particular clauses of this Standard, this Standard shall prevail unless determined otherwise by the Railway Infrastructure Manager

1.4 Referenced documents

The following documents are referred to in this Standard:

- (a) National Safety Law as enacted in each state or Territory
- (b) AS 2601: The Demolition of Structures
- (c) AS 4292: Railway Safety Management
- (d) AS 5100: Bridge Design
- (e) AS 7630: Railway Infrastructure - Track Classification
- (f) AS 7636: Railway Infrastructure - Railway Structures
- (g) AS 7644: Railway Infrastructure - Rail Corridor Access
- (h) AS 7645: Railway Infrastructure - Rail Corridor Management
- (i) Australian Rainfall and Runoff - A Guide to Flood Estimation

1.5 Definitions

Specific terms used in this Standard are defined below:

Afflux: A rise in the water level immediately upstream of and due to an obstruction. An example of afflux is provided in Appendix 1.

Annual Exceedance Probability (AEP or Probability of Exceedance): The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year. AEP is usually expressed as a percentage, and common references include 1% AEP and 2% AEP.

Airborne Laser Survey (ALS): Technology for collecting large areas of elevation data. Through the use of aircraft mounted laser technology millions of data points over a survey area are gathered without the need for extensive ground access.

Average Recurrence Interval (ARI): The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that the periods between exceedances are generally random. ARI is generally expressed as years, and common references include 1 in 2-year ARI, 1 in 10-year ARI, 1 in 50-year ARI, and 1 in 100-year ARI.

Ballast Pocket: A depression in the ballast beneath the railway track. A ballast pocket may form under each rail as a result of repeated loading by passing trains. Track raising to offset subgrade settlement causes the ballast depth to increase. Evidence of ballast pockets can take a variety of forms, including a heaved formation.

Baseflow: is the discharge into a stream-flow from natural storages, particularly sustaining flow between rainfall events. For example, when groundwater provides the entire flow of a stream, baseflow conditions are said to exist.

Calibration (Model Calibration): The hydrologic and hydraulic model calibration process consists of systematically comparing observed values (such as runoff quantities or flooding behaviour) within the study area against the hydrologic or hydraulic model's reproduction of that behaviour. This process generally incorporates comparisons between gauged stream flow data, gauged or observed flood levels, and areas of inundation.

Catch Bank: A small earthen mound benched into the natural surface, similar to a levee. A catch bank prevents the need for excavation of a catch drain by forming the catch drain at the natural surface level.

Catch Drains: Catch drains (also known as "top drains") intercept overland flow or runoff before it reaches the track. Catch drains are generally located on the uphill side of a cutting to catch water flowing down the hill and remove it prior to reaching the cutting. An example of a catch drain is provided in Appendix 1.

Catchment (Catchment Area): The land area draining to a point of interest, such as a point on a stream, river or stormwater drainage system. The catchment area is used to determine the quantity of runoff through hydrological assessment. An example of catchment is provided in Appendix 1.

Cess Drains: Cess drains are surface drains located at the formation level at the side of the tracks. They remove water that has percolated through the ballast and is flowing across the capping layer towards the outside of the formation. Cess drains are primarily intended for protect the formation by keeping it dry. An example of a cess drain is provided in Appendix 1.

Coefficient of Discharge: The coefficient of discharge, C_y , where y represents "years", is a coefficient used within the Rational Method. The value of C_y is a statistical composite of infiltration and other losses, and to some degree, channel storage.

Critical Flood Duration: The duration of a nominated storm event that results in the maximum flood discharge for the specified area.

Cross Drainage: A system of pipes or culverts which conveys storm flows transversely across or under a railway. An example of cross-drainage is provided in Appendix 1.

Cut or Cutting: An earth and/or rock excavation that is made below an existing surface to create the railway formation

Daylighting: A pipe outlet resurfacing to the atmosphere or a swale moving out of a cutting.

Design Event: An event for which stormwater infrastructure and mitigation is designed.

Discharge: The rate of flow of water measured as a volume per unit of time.

Drain Block: Located within a cess drain, a drain block slows the velocity of water, reducing the likelihood of scour and erosion. Drain blocks are usually concrete structures and are typically positioned at the location where a cess drain transitions from cutting to embankment.

Encroachment: An alteration to the existing topography (such as railway infrastructure or placement of fill) in the floodplain, so that it reduces the area available to convey floodwaters.

Energy Dissipater: Any device designed to protect downstream areas from erosion and scour by reducing the velocity of flow to acceptable limits.

Erosion: The process by which the flow of water alters the ground surface in an area by removing layers of soil.

External Catchments: A catchment that is not directly connected to the stormwater infrastructure, but still has an impact. An example of an external catchment is provided in Appendix 1.

Flood: Relatively high water levels caused by excessive rainfall, storm surge, dam break or tsunami that overtop the natural or artificial banks of a stream, creek, river, estuary, lake, dam or drainage system.

Flood Frequency Analysis: A flood frequency analysis is an analytical technique that involves using observed annual peak flow data to calculate statistical information such as annual recurrence intervals (or annual exceedance probability).

Flood Immunity: A measure of the protection provided to infrastructure for a certain flood event (i.e. a bridge that is considered to be immune to a 100-year ARI flood is predicted to not be overtopped during this event).

Floodplain: A floodplain is defined as the extent of land inundated by the probable maximum flood (PMF). A floodplain is usually the flat area to either side of the main channel(s). An example of a floodplain is provided in Appendix 1.

Floodway: This is the part of the floodplain specifically designed to carry flood flows, and ideally capable of containing the "Defined Flood Event".

Fluvial Geomorphology: Fluvial geomorphology is the examination of land formed by flowing water either through erosion or deposition and is usually undertaken in relation to dynamic equilibrium. For example, if a creek has not achieved dynamic equilibrium it is more likely to move with the landscape through erosion and deposition and therefore if changes are made to the creek, additional design may be required to manage the erosion and deposition impacts.

Fraction Impervious: The part of a catchment which is impervious, expressed as a decimal or percentage.

Freeboard: The difference in height between the calculated water surface elevation and the top, obvert, crest of a structure or the floor level of a building, and provided for the purpose of ensuring a safety margin above the calculated design water elevation.

French drain: a trench filled with gravel or rock or containing a perforated pipe that redirects surface water and groundwater away from an area.

Gabion: A cage, cylinder or box filled with rocks, concrete or, sometimes, sand and soil. Gabions can be in the form of reno mattresses which are low in height relative to the lateral dimensions.

Hydraulic Grade Line: A line representing the pressure head along a pipeline, corresponding to the effective (free) water surface elevation in the piped portions of the stormwater drainage system.

Hydraulic Gradient: Also known as "friction slope", hydraulic gradient is the slope of the hydraulic grade line.

Hydraulic Modelling Extent: The area of interest where hydraulic modelling (usually flood modelling) is to occur.

Hydraulics: The study of flow characteristics around and through hydraulic structures such as bridges, culverts and weirs, and can also refer to determination of the lateral and vertical extent of a particular flood or overland flow path.

Intensity Frequency Duration: The basic rainfall data used in the calculation of rainfall runoff rates.

Mainstream Flooding: Mainstream flooding refers to the inundation which occurs when runoff from a catchment into streams and rivers continues to rise and overtops the waterway channel. The area affected by flooding is generally referred to as the floodplain.

Manning's Roughness Coefficient: A measure of the surface roughness of a conduit or channel to be applied in the Manning's equation.

Meandering: The bending or directional curving of a channel, river or creek.

Mitre Drains: Mitre drains are connected to cess and catch drains to provide an escape for water from these drains. Mitre drains should be provided at regular intervals to remove water before it slows down sufficiently to deposit any sediment that it may be carrying. An example of a mitre drain is provided in Appendix 1.

Model Calibration: Model calibration is a process of systematically adjusting model parameter values to attain a set of parameters which provide the best estimate of the observed stream flow.

Mud Hole: A generic term used to describe a condition where the sleepers appear to be surrounded by mud rather than ballast. Mud holes form as a result of repeated loading by passing trains when the ballast punctures the capping layer and mud is pumped up from the soft subgrade.

Rational Formula (or Rational Method): The expression of peak discharge as proportional to the product of rainfall intensity, catchment area and a runoff coefficient dependent on the catchment basin characteristics.

Reno Mattress: A large unit constructed of woven wire mesh and filled with stone at the site of construction to form a flexible structure for river and channel bed erosion protection. Reno mattresses are used for river and channel bed protection, unlike Gabions which are located in bank protection or walling works.

Reservoir Area: A lake, natural or artificial river pool, or other inland waters on which waves may be generated.

Riparian: A zone or area that is the interface between land and a river or stream.

Rip rap (rip-rap): Rocks or other material used to protect shorelines, streambeds, bridge abutments, pilings and other shoreline structures against scour, water or ice erosion. May be grouted or ungrouted.

Runoff (also known as "Surface Runoff" or "Rainfall Runoff"): Runoff is the water flow that occurs when the soil is infiltrated to full capacity and excess rainwater flows over the land.

Standard of Service (in relation to flooding): The service provided by flood mitigation or stormwater infrastructure for a certain event.

Stormwater Flooding: Stormwater flooding refers to the inundation that occurs when runoff from the catchment exceeds the capacity of the stormwater drainage system and passes overland. In general, areas affected by overland flows are referred to as overland flow paths.

Tailwater: The receiving water located immediately downstream of an area or structure of interest. Tailwater includes oceans, rivers, creeks, lakes and basins, and can either be considered as steady state or varying over time.

Throughflow: The lateral unsaturated flow of water in the soil zone. Once water infiltrates into the soil it is affected by gravity and either infiltrates to the water table or travels downslope. Throughflow normally takes place when the soil is completely saturated with water.

Underground Drain: A piped drain located in a narrow cutting, tunnel, throughout station pits, platforms, yards or areas within the suburban system. Underground drainage is usually sized to cater for a smaller design storm than open channels due to cost and construction efficiency.

Wild Rivers: Rivers that are in near pristine condition in terms of animal life, plant life and water flow and are not impacted by manmade structures such as dams and levees. Wild rivers have natural rates of siltation or bank erosion.

Windrow: The build-up of material on the edge of newly graded catchdrains. Windrows act as the drain embankment or small levee. Similar function to a 'Catch Bank' but without being benched into the natural surface.

1.6 Abbreviations

AEP – Annual Exceedance Probability

ALS – Airborne Laser Survey

ARI – Average Recurrence Interval

AR&R – Australian Rainfall and Runoff

BoM – Bureau of Meteorology

Cy - Coefficient of Discharge

GIS – Geographical Information Systems

IFD – Intensity Frequency Duration

LIDAR – Light Detection and Ranging, or Laser Imaging Detection and Ranging.

2 Flood Risk Management

2.1 Overview

Flood risk to railway infrastructure and personnel shall be mitigated through adequate planning and design procedures outlined in this Standard, and the development of a Flood Management Plan and Emergency Response Plan.

Flood risk extends to:

- (a) Infrastructure and property, such as:
 - i. railway infrastructure including stations, signals, rolling stock, track and yards
 - ii. public and private infrastructure including roads and properties.
- (b) Operations, such as:
 - i. closure of railway causing operational delay
 - ii. derailment due to track failure as a result of flooding.
- (c) Humans, such as:
 - i. drowning or injury due to direct contact with flood waters
 - ii. derailment due to track failure as a result of flooding.
- (d) The environment, such as:
 - i. changes in flow regime and flood characteristics

- ii. erosion, scour, sedimentation and debris
- iii. potential water quality issues.

Managing risks from flooding may include improving the flood immunity of railway infrastructure and surrounding areas, as well as reducing the impacts of flooding by minimising the railway's vulnerability and exposure to flooding.

Flood risk management should be addressed in a Flood Management Plan and include the following:

- (a) Flood hazard identification
- (b) Flood risk assessment
- (c) Emergency response plan
- (d) Flood management and mitigation
- (e) Flood warning system
- (f) Vulnerability assessment
- (g) Identification of roles and responsibilities.

2.2 Flood Management Plan

A Flood Management Plan is a formal plan to deal with the threat, onset, occurrence and aftermath of a flood.

A Flood Management Plan should be developed and implemented based on the Flood Risk Assessment and should include flood mitigation measures.

The Flood Management Plan should be a dynamic document that is periodically reviewed, updated and improved based on triggers, as determined by the Railway Infrastructure Manager, which may include:

- (a) seasonal changes (i.e. approaching storm season)
- (b) a flood event
- (c) infrastructure changes

The objectives of a Flood Management Plan should include:

- (a) Ensuring that drainage and flood management throughout the railway corridor is effectively managed and co-ordinated through the railway organisation and external agencies;
- (b) Understanding of flood risks, and identifying extreme or intolerable flood risks and areas that experience frequent flooding;
- (c) Identifying gaps and improvement actions that are needed to address existing and future risks and to better prepare for and manage floods;
- (d) Clarifying the roles and responsibilities of stakeholders in addressing existing and future flood risks.

2.3 Flood Hazard Identification

Flood hazard is considered as the potential for inundation that involves risk to life, health, property, or natural floodplain resources or functions:

- (a) Flood hazard is usually determined by undertaking flood modelling and is comprised of three elements:
 - i. severity (magnitude, duration and extent of flooding)
 - ii. probability of occurrence
 - iii. speed of onset of flooding

Waterway and drainage systems with identified flood hazards and history of flooding shall be nominated as "hazard locations".

- (a) Some hazard locations may experience frequent flooding while others may only be affected by severe storms.
- (b) The Railway Infrastructure Manager shall ensure that potential flood hazards are identified and the monitoring, maintenance and infrastructure requirements for these hazard locations are understood.
- (c) One method of achieving this is a Risk Assessment process, although detailed historical and contemporary records should also be established and maintained.

2.4 Flood Risk Assessment

The construction of Infrastructure in flood prone areas generally causes a flood risk which shall be quantified and managed as deemed appropriate by the Railway Infrastructure Manager.

Flood risk includes both the chance of an event taking place and its potential impact.

The level of flood risk may be associated with a number of factors including:

- (a) Flood hazard
- (b) Flood warning times
- (c) Speed of flooding onset
- (d) Duration of flooding
- (e) Property inundation
- (f) Emergency management during major floods.

The Flood Risk Assessment should include:

- (a) Tolerability of the existing flood risk
- (b) Location of existing flood risks
- (c) Future flood risks
- (d) Cultural and social impact.

During any risk assessment or flood hazard identification process consideration should be given to the possibility that areas directly outside of these hazard locations may also find themselves at considerable risk.

2.5 Flood Management and Mitigation

Flood management and mitigation should be addressed in a Flood Management Plan through the following flood management procedures:

- (a) Development of a drainage and floodplain strategy

- (b) Track layout, planning and drainage design
- (c) Flood modelling and mapping
- (d) Asset management
- (e) Data management
- (f) Flood Emergency Response Plan
- (g) Driver education and awareness
- (h) Passenger and community information and awareness
- (i) Flood Warning System
- (j) Drainage guidelines.

Flood risk is harder to manage with existing railway infrastructure than with Greenfield works but modification measures such as installation of dams or levees can change the behaviour of floodwaters. Similarly, track modification measures can protect against harm caused by floods.

Improving the flow conditions of existing infrastructure can minimise afflux and inundation.

The methods that are effective in reducing flood risk are very location-specific. There is no common solution, and a variety of measures is generally necessary to reduce risk.

Maintenance of infrastructure and protection of existing embankments can avoid piping failure and minimise erosion at culverts and bridges.

2.6 Flood Warning System

A flood warning system or process shall be in place for flood-prone areas.

The flood warning system should:

- (a) Include the use of BoM flood warning information, or a stream flow or rain gauge warning system
- (b) Be reviewed periodically in accordance with the Flood Management Plan or, where appropriate, in collaboration with other relevant authorities.

An appropriate level of communication shall be provided between the Railway Infrastructure Manager, affected staff and the train control centre to advise of potential flooding.

2.7 Flood Emergency Response Plan

A Flood Emergency Response Plan should be prepared in accordance with the RISSB National Guideline - Rail Emergency Management Planning and any federal, State or Territory disaster plan requirements.

All flood emergency management and response procedures should be adhered to.

3 Design Flood and Drainage Standards

The hydraulic assessment and subsequent design of drainage infrastructure are critical to enable the track bed to successfully withstand the high stresses from track loads and exposure to environmental conditions. Common track problems such as loss of alignment, gauge, mud pumping and ballast fouling can often be traced to deficiencies in drainage characteristics which stem from inadequate or inaccurate assessment of the hydraulic and hydrological requirements.

Any flood and drainage design shall take into account environmental considerations and regulations

The requirements of local state and/or governing municipalities shall be considered for any discharge especially in regard to water quality.

3.1 Hydrological Assessment

Any hydrological assessment shall be undertaken in accordance with the methods provided in the Australian Rainfall and Runoff Guidelines, or industry good practice.

A hydrological assessment should predominantly be undertaken during the preliminary planning phase of a project and prior to the hydraulic analysis. This ensures that the key factors influencing the hydraulic and environmental performance of drainage infrastructure are identified and understood prior to concept and detailed design.

A hydrologic assessment should include the following:

- (a) Identification of study area (i.e. hydraulic model extent)
- (b) Collection and review of available relevant information
- (c) Identification of catchment areas and characteristics
- (d) Determination of hydrologic computational method
- (e) Selection of design events
- (f) Validation and calibration of results
- (g) Sensitivity analyses.

A risk assessment should also be undertaken to determine the complexity of the hydrological assessment required.

3.1.1 Identification of Study Area (Hydraulic Model Extent)

The study area should be defined by the extent and complexity of the drainage system across or alongside the railway in relation to flooding characteristics:

- (a) This area is generally covered by the hydraulic model extent which influences catchment delineation and the required locations for design inflow from the hydrology model as an input into the hydraulic model.

The hydraulic model extent should be determined prior to the hydrological assessment:

- (a) It should, however, be noted that alteration to the hydraulic modelling extent may be necessary throughout the hydrologic and hydraulic assessment and design process.

Any hydrological assessment shall be undertaken in accordance with the methods provided in the Australian Rainfall and Runoff Guidelines, or industry good practice.

The coverage of the hydraulic study should include the areas which may be affected by potential rises in floodwater due to railway structures and by potential changes to the floodway alignments as a result of long term channel meandering.

3.1.2 Collection and Review of Relevant Information

The quantity and quality of data available to undertake a hydrological assessment shall be determined at the outset of the project as this can influence the selection of the hydrologic